Critical Assessment of Technologies

2002

Performed by the

Advisory Group on Electron Devices

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Introduction

The United States became and has continued to be the dominant military superpower in the world, based both on superior systems and superior embedded enabling technology – especially ***electronics,*** including sensors of many types. The term "electronics" is used here to denote the broader field of digital electronics, microwave, optical, and newer research areas– all of which are important today and in the future for diverse defense systems. The goal of the Department of Defense's science and technology programs is to maintain and further that dominance. Science and technology efforts yield benefits to the warfighter that are several orders of magnitude beyond the costs of their development. Electronic devices, components and systems form the core of all our advanced weapons systems, radars, satellites, communications, and command and control networks as well as portable electronics, for the warfighter on all platforms of future combat and intelligence systems of the 21st century.

A paradigm shift in system development has been introduced by DoD in the past decade which modifies the historical context of the S&T program. The S&T program is strongly affected by two elements of that paradigm:

- Increased use of available COTS components in military systems, and
- Greater reliance on our system development expertise.

These elements have been proffered by DoD strategists to maintain and enhance our military systems' superiority, targeting cost reduction.

However, there is a fundamental uniqueness to the role electronics plays in today's military and a proper balance between S&T activities and the paradigm shift are essential for warfighter superiority. Electronics is a pervasive enabling technology and the anticipated S&T advances will provide a continuing robust foundation for everything new and improved, from laser weapons to the Army's Future Combat System.

The warfighter will benefit from unique military electronics by many pathways, e.g.,:

- Distributed and high range, standoff sensors
- Precision high range standoff weapons
- Mobile integrated land, sea and air forces – both platforms and warfighters

In the past, development of these underlying electronics capabilities was accomplished through ambitious S&T programs within the military and among its contractors. Over the past 10 years, however, this situation has changed as a result of the decline in defense spending brought on by the end of the Cold War. Budget planners have found it easier to make large cuts in the research and development of future technologies rather than reduce spending on current programs. The effects of these cuts have had a severe impact on the state of the DoD's S&T programs, especially in electronics, and the evolution of new technologies for future insertion.

The DoD's technological advantage is eroding. Our technological lead over our adversaries cannot be maintained using only this method of COTS, as commercial products are, by definition, available to all countries, friend and foe alike. The development of unique defense electronics, as well as advanced electronics prior to commercial availability, must now be renewed as a critical DoD investment in order to maintain superiority. Many new S&T areas (nanoelectronics, bioelectronics, wide bandgap, power and energy generation, photonics, millimeter-wave electronics, etc.) are expected to provide robust drivers to achieve a superior 21st century warfighter capability.

This report is intended to present an overview of current ongoing key electronics science and technology issues facing the DoD. It is also intended to familiarize the DoD leadership with the role that the Advisory Group on Electron Devices plays in helping to address these issues. It is not intended to portray an in-depth survey, but rather highlight areas of concern that should be addressed immediately.

Comments or questions about this report, as well as requests for additional copies, should be directed to the Secretariat for the Advisory Group on Electron Devices:

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Overview

Role of AGED within DoD

The Advisory Group on Electron Devices (AGED) serves as the preeminent organization charged with providing the Department of Defense (DoD) with timely, comprehensive and independent advice and information with regard to DoD's electronics science and technology (S&T) programs.

AGED is populated by experts in electronics S&T from industry, academia and the military. Its members serve as an external peer review to top-level DoD decision-makers in the electronics arena. Additional details regarding AGED's composition and its charter are available on the Web at http://aged.palisades.org. A partial listing of AGED members can be found at the end of this report.

AGED consists of its principal group and three Working Groups. These Working Groups are comprised of technology experts from industry, academia and the military, and each group focuses on a particular subarea of electronics:

- Working Group A: Microwaves and RF Components, Electronic Materials
- Working Group B: Microelectronics and Electronics Integration Technology
- Working Group C: Electro-Optics

Purpose of This Report

This report is intended to provide a top-level review of critical technology areas of concern to DoD. These technologies are identified by AGED through its STAR process (see below) and its ongoing interaction among its representatives from the military, industry and academia. In addition, this report discusses the new Advanced Electronics Initiative currently being developed and implemented within the DoD. This report also presents a top-level view of the status of various high-leverage electronics technologies.

Electronics Roadmaps

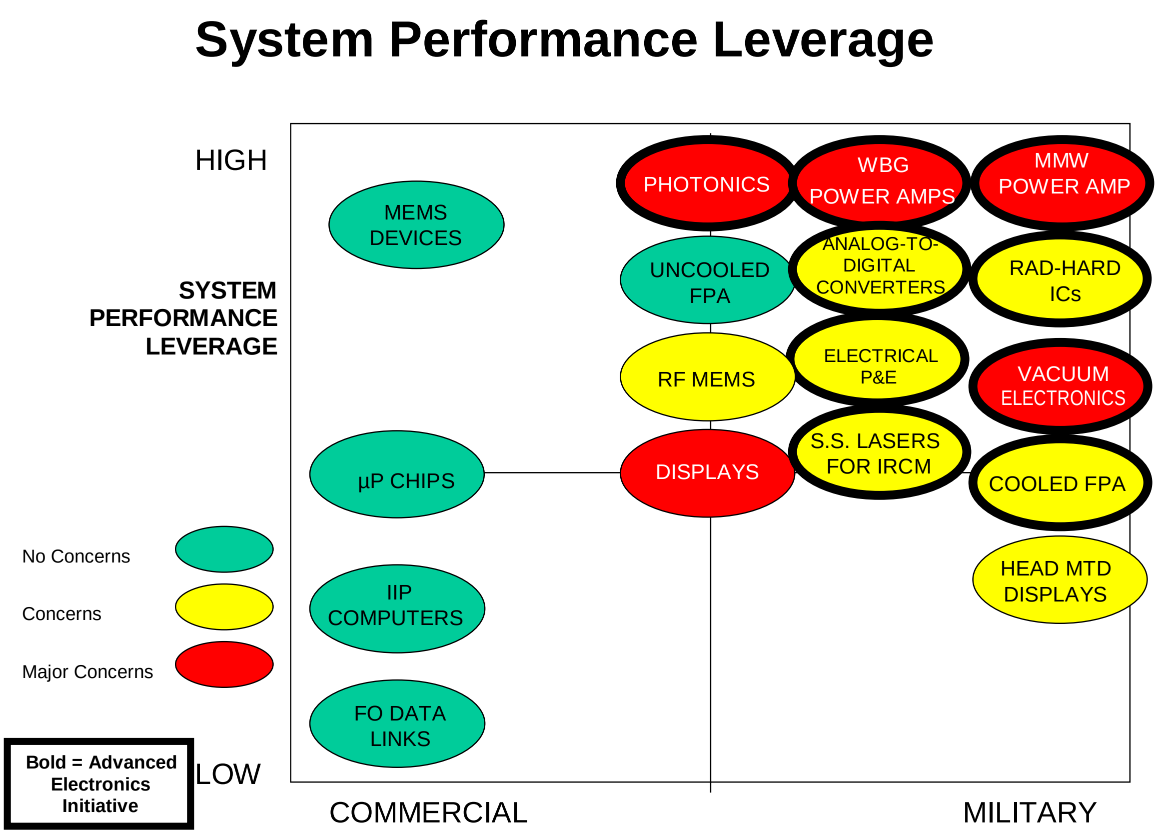
In response to an issue raised at the 1999 Electronics Technology Area Review and Assessment (TARA), a set of technology roadmaps was developed by the DoD Technology Panel for Electron Devices (TPED). These TPED Roadmaps describe sixteen areas of electronics and identify key technology milestones, potential insertion points into DoD systems, the maturity of the individual technology efforts within each area and the level of funding applied to each effort. TPED Roadmaps play a key role in determining the state of DoD's S&T efforts in these areas, the adequacy and timing of investment, and aid in the planning and conduct of STARs as well as the identification of endangered technologies. These roadmaps are living documents, and undergo constant scrutiny and revision by AGED's three Working Groups that regularly submit revision recommendations to TPED. Further information on these roadmaps is available from the AGED/TPED Secretariat at the contact information provided in the Executive Summary.

List of Current TPED Roadmaps	
Antennas Design, Modeling and Simulation Displays Electronic Materials Energy Conversion Focal Plane Arrays Frequency Control MEMS	Packaging and Interconnect Photonics and Lasers Rad Hard Microelectronics RF MEMS RF Receiver Components RF Solid State Power Amplifiers Vacuum Electronics

System Performance Leverage

It is widely recognized that electronics is largely an enabling technology, rather than an end-use technology. Electronics forms the core of a wide variety of DoD systems from smart weapons to radars to communications. By their nature, the electronics technologies needed to build these systems are not always obvious. To help in identifying those technologies that are most critical to the DoD, AGED has compiled its "System Performance Leverage" chart.

This chart strives to identify key electronics technologies in general and to draw specific attention to those technologies in need of attention. In many cases, these technologies may be underfunded or may suffer from a lack of coordinated effort or oversight. The current System Performance Leverage chart is shown below.



Technologies are graded on a continuum based on their applicability to the military and/or the commercial sector, and on the leverage value of that particular technology. Items with bolded boundaries, as indicated, are included in the Advanced Electronics Initiative.

Many of the technologies included in this chart will be further discussed later in the report, either as part of the Advanced Electronics Initiative and/or in conjunction with an AGED STAR.

DoD Advanced Electronics Initiative (DAEI)

Introduction/Background

DoD unique electronics and electron devices are critical and pervasive technologies that enable required warfare capabilities for current and future missions. Current investment resources and budgets are not consistent with meeting the warfare requirements. In today's environment of dramatic change and transitional focus, the balanced S&T investments in technology areas and maturation levels of electronics are below the threshold to meet the performance and timing entry points for transition to the acquisition community. This transition gap continues to widen as Service and Agency investments have become more focused on narrow and limited application areas. The "DoD Advanced Electronics Initiative" (DAEI) was initiated by USD(AT&L) and DUSD(S&T) in July 2001 as an enabling technology supported by the FY02 amended budget. The DAEI is a subset of the total DoD electronics program with thrusts in electro-optics/infrared, RF power, mixed signal, and radiation hardened electronics component technologies. The thrusts were selected on the basis of potential payoff, time critical opportunity, DoD-wide application, and lack of current commercial support. Service or Agency leads for thrusts or sub-thrusts were assigned by USD(AT&L). The Services and Agencies were asked to identify program funding for these technologies in accordance with the roadmaps.

DAEI Thrusts

- **Advanced RF Power Components**
  - "***Control the RF spectrum***"- RF power sources to enable domination of the electromagnetic battlespace
- **Radiation Hardened Microelectronics**
  - "***Close the performance gap***"-Advance radiation hardened microelectronics to near mainstream
- **EO/IR**
  - "***Complete Gen-III*** " Multicolor Infrared Focal Plane Arrays and Semiconductor Lasers for enhanced RSTA and platform survivability
- **Mixed-Signal Technology**
  - "***Break the bottleneck***" Adaptable, real-time information processing between signal acquisition and user information

RF Power Components Thrust

The RF Power Components Thrust consists of four areas: Wide Bandgap Solid State Technologies, Vacuum Electronics, Millimeter Wave Solid State Technologies, and Producible Microwave Solid State Component Technologies. Specific technology areas that are being addressed include:

- WBG High Power MMICs
  - Efficient, compact, reliable, affordable
  - Application space: 3-35 GHz
  - High power, bandwidth, data rate and efficiency
- Vacuum Electronics
  - Affordable compact wide bandwidth MPM and MMPM with high efficiency and linearity
  - Millimeter-Wave high power
  - Multiple beam amplifiers
- InP Millimeter-Wave Solid State Technology: affordable performance up to 100 GHz
- GaAs MMICs Beyond COTS: high yield manufacturing

The focus of the RF Power Thrust is to ensure availability of state-of-the-art RF power components to meet performance needs of emerging DoD systems.

Mixed-Signal Thrust

The Mixed-Signal Thrust addresses the DoD need for rapidly and adaptively acquiring and processing large quantities of diversified sensor signals to enable the warfighter to prosecute time critical targets and threats. A technology revolution will be required to overcome current signal processing limitations:

1. DoD speed and adaptability needs exceed commercial sector
2. Near-Real-Time signal processing of large amounts of information creates unique DoD challenges
3. Need for operation in extreme jamming environments and co-site inference not addressed by commercial applications
4. Future military needs will not be meet by commercial technologies

The Mixed-Signal Thrust is composed of two technology focus areas:

- Digital/Analog/RF/MEMS
  - Advanced ADCs, DACs, & DDS
  - Antimonide-based compound semiconductors (ABCS)
  - NeoCAD (Both electronic & photonic)
  - Technology for Efficient Agile Microelectronics (TEAM)
  - Vertically integrated semiconductor arrays

- Photonics/MOEMS
  - Advanced optical processing
  - Chip scale WDM
  - Photonic ADC
    - VLSI photonics
    - Agile wideband receiver

Electro-Optics and Infrared Thrust

The Electro-Optics and Infrared Thrust addresses two areas: lasers and IR focal plane arrays. Specific thrust challenges include:

- MCT IR Focal Plane Arrays
  - Integrate small pixels/large area arrays/MBE on silicon substrates (e.g., for MWIR)
  - Improve MBE scale-up to large substrates
  - Develop lattice matched heterostructures for multiband arrays
  - Develop small pixel-multicolor and specialized ROICs for SWIR
  - Develop high resolution, high performance, multicolor large area infrared imagers
  - Develop higher temperature, high sensitivity IRFPAs
  - MCT/ROIC to achieve small pixels with high quantum efficiency, VLWIR, etc.
- Lasers
  - Develop high efficiency and improved thermal management technology for room temperature, solid-sate MWIR operation (adequate peak power already achieved at cryogenic temperatures)
  - Develop increased spectral diversity to provide IRCM in all IR bands containing threats
  - Develop quantum cascade and interband cascade semiconductor lasers for room temperature operation at MWIR CM wavelengths and powers
  - Develop high power 1.5-2.0 µm solid-state sources.

The focus of the thrust is directed at:

1. Affordable high performance sensors for improved RSTA, BMD, countermine, air defense, threat warning and development of lasers for missile countermeasures.
2. Third generation focal plane arrays (very large format single band and multicolor/dual band) will enable major advances in FLIRs, reconnaissance, surveillance, targeting & acquisition (RSTA), platform protection (threat warning) and ballistic missile defense.
3. Diode pump arrays and mid-wave infrared (MWIR) semiconductor diode lasers will enable more efficient lasers for battlefield countermeasures and provide a revolutionary capability in air platform protection.

Radiation Hardened Microelectronics Thrust

Military space assets are strategic worldwide communication and surveillance assets for all of the networked U.S. defense forces. These strategic space defense satellites must survive the defined military nuclear event threats, and must continue to operate as intended through its aftermath. Hence, the military space radiation requirements for microelectronic chips are more stringent than for commercial spacecraft and require higher survivability and functionality thresholds.

The Radiation Hardened Microelectronics Thrust addresses affordable technology to provide leap-ahead performance in radiation hardened microelectronics to satisfy next-generation space system needs. Accomplishing this goal requires improved design and manufacturing techniques and innovative multifunctional device concepts. Key objectives of this thrust include:

- Invest in two principal rad hard digital microelectronics suppliers.
- Upgrade facilities necessary to support fabrication of 0.15-μm radiation-hardened microelectronics within 3 years.
- Develop and demonstrate radiation-hardened 0.15-μm process and design rules with prototype demonstration after 3 years.
- Ensure economic viability of rad hard suppliers through the performance of marketing analysis and implementation of strategic business plan.
- Implement a long term (8-year) agreement with vendors to maintain radiation-hardened production capability.

The Radiation Hardened Microelectronics Thrust ensures infrastructure can manufacture rad hard electronics to meet performance of emerging DoD systems including:

- Space based radar
- Hyperspectral imager
- Surveillance systems
- Missile system upgrades
- Space electronically agile radar
- Other Government agency systems

Summary

The DAEI is underway and building consensus across the DoD. The advantages of the initiative are:

- Critical funding to mature, transition, and insert technology
- Facilitates development and use of common components in systems
- Integrated—considers all Defense needs—avoids stovepipe solutions
- Draws on expertise across the Services

Critical Technologies Identified Through STARs

AGED conducts Special Technology Area Reviews (STARs) on topics of keen time-sensitive interest to DoD. The impetus for STARs could develop from external forces such as industry consolidation, technological forces such as a critical development and/or maturation point for a specific technology or field, or internal DoD forces such as policy decisions.

These STARs are tailored to address the impact of these forces with respect to top-level DoD guidance. In addition, the unique nature of electronics S&T (see System Performance Leverage, above) serves as a basis for the review of these topics and the ultimate findings and recommendations.

A STAR is a one to three day intensive review of a specific technology area. Participants and presenters include representatives from prime contractors, system program offices, Service laboratories and DARPA, and top-level DoD management. A STAR Committee is convened by AGED, consisting of subject matter experts from among AGED's ranks, to review the information provided by these presenters and to resolve the key issues raised in the STAR's defining Terms of Reference. The result of these STARs is a tightly focused intensive review of a given technology, market, or policy, and a recommended course of action for DoD to pursue.

STARs are conducted on an ad hoc basis to address technologies of immediate and critical importance to DoD. What follows in this section is a summary of the various technology issues that have been reviewed by AGED over the past couple of years and the result of AGED's review.

RF MEMS[1]

MEMS (Microelectromechanical Systems) constitute an exciting but broad area of research and technology. RF applications for this technology include switches in radar systems and filters in communications systems. DoD interest in this area is high, due to the possibility of utilizing these devices in order to significantly upgrade current and future radar architectures by developing high-performance, low-cost, and low-power consumption parts based on RF MEMS technology. The high-payoff of the technology has not yet been realized, and AGED determined that a STAR was required to investigate the problems and investment strategy of this technology.

The presenters at the STAR agreed that, while the RF MEMS technology has demonstrated the potential to revolutionize the architecture of modern communications systems, it has not been designed for specific reliability requirements. The technology development moved quickly from initial prototype demonstrations to full-scale insertion,

[1] The full title for this STAR is "RF MEMS Technology." The final report is not yet available for public release. Information regarding this report is available from the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

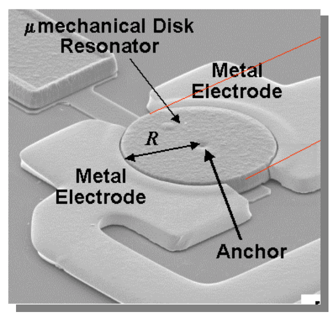
thus bypassing the required research and development that would lead to technology maturity and development of a design process-for-reliability.

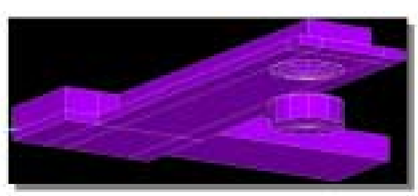
AGED recommended that the problems illuminated in the STAR be addressed by the following:

1. Develop an integrated DoD roadmap for RF MEMS that shows past, current, and essential, but presently unfunded, efforts.
2. Fund a research program, as indicated by the roadmap, that addresses the fundamental science and technology problems that have been identified in the report.
3. Provide a significant level of funding for RF MEMS which can be termed "supporting efforts" such as packaging, design tools, etc.
4. Encourage sharing, with related US industrial organizations, critical results from Government funded efforts in modeling, failure analysis, and life support.
5. Provide incentives for technology insertion.

The detailed findings and recommendations can be found in the full report.

STAR on RF MEMS



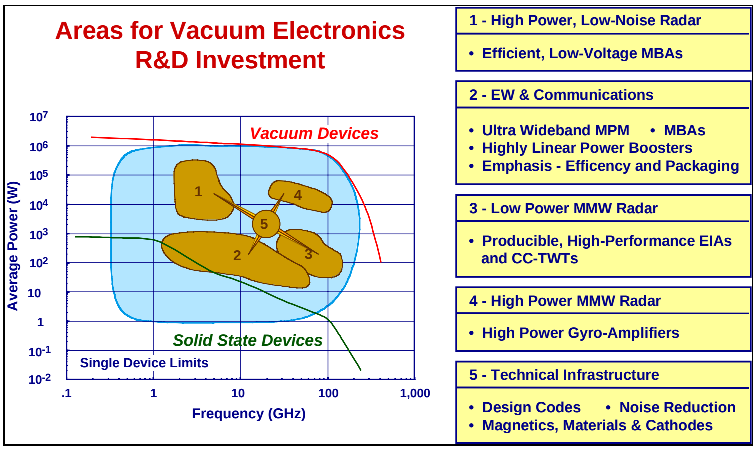


Problem	Cause
Dielectric Charging	High Voltage on Dielectric
Curling, Warping	Stress Gradients, Thin Layers
Stiction (surface fluids) (Van der Waals)	Low Restoring Force
Stiction (RF)	Low Restoring Force / High RF Power
High Actuation Voltage	High Spring Constants
Contact Degradation	High RF Power
Contact Welding	High RF Power

Reliability should be an integral component of the RF MEMS design process. Efforts to push these devices toward rapid integration have overlooked reliability concerns, which will ultimately drive up life-cycle costs considerably.

Vacuum Electronics[2]

Vacuum electronics technology is used in numerous DoD systems. Large-scale devices are used in high bandwidth and high power communications and RF applications. Smaller devices (e.g., microwave power modules (MPMs)) are used in applications such as electronic warfare decoys, jammers, and communications.



Vacuum Electronics serves a vital purpose in many military applications requiring high power and high bandwidth.

However, DoD funding cuts for vacuum electronics S&T since 1995 are severely limiting the rate of technology advancement and the development of new devices needed for current and future systems. Further cuts threaten the entire VE S&T program and the U.S. technology base. There is no comparative commercial driver for this technology, and is the responsibility of the DoD to maintain.

AGED conducted a STAR in December 2000 to address the problems and explore possible solutions. AGED concluded that DoD investment in this area should be increased to approximately $27M per year and stabilized for a minimum of five years. The funding would be spread amongst universities, industry and industry suppliers, and DoD laboratories. In addition to the S&T efforts, ManTech and Title III programs are also included in the $27M. The STAR also concluded that alternative technologies are not yet mature enough to consider abandoning VE technology for critical applications.

AGED recommended that the funding be allocated within the following areas:

1. Applied Research ($12M/year for a minimum of 5 years)
2. Advanced Development ($10M/year for a minimum of 5 years)
3. Basic Research ($5M/year for 5 years)

Recommended additional investments outside of the S&T community include:

1. Legacy Systems ($2 to $4M/year as needed)
2. Microwave Power Module ManTech ($5 to $7M/year for 3 years)
3. Industrial Infrastructure ($3M/year for 5 years)

[2] The full title for this STAR is "Vacuum Electronics Technology for RF Applications." The final report is not yet available for public release. Information regarding this report is available from the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

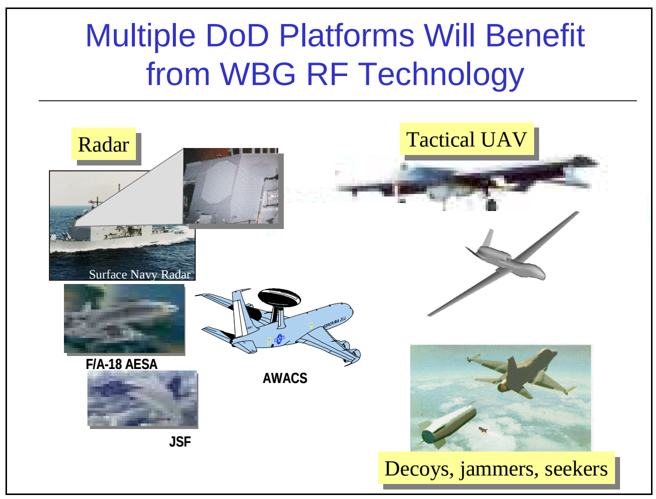
The full details of these findings and recommendations can be found in the report.

As the figure above illustrates, vacuum electronic devices operate at power levels several orders of magnitude above the state of the art in single wide bandgap solid state devices. For many applications, especially radar, vacuum electronic devices remain the critical – and only – option for use in DoD systems.

Wide Bandgap Electronics[3]

Wide bandgap materials include silicon carbide (SiC) and gallium nitride (GaN). These materials could be used to develop RF devices of higher power and frequency than current solid state materials (e.g., Si, GaAs). Wide bandgap RF electronics is the use of SiC and/or GaN materials and devices meet future warfighter needs in multifunction radars, jammers, and decoys. Current limits on solid-state technology utilizing existing materials necessitate exploration of alternatives. The application of this technology is highly specific to DoD needs. Commercial applications exist for light-emitting diodes, but these applications do not require nearly the material quality or complexity for military use.

Currently, the quality and price of either material is not sufficiently low for the DoD. Since there is no direct commercial driver, the DoD will need to invest significant funding in order to evolve this technology for use by the warfighter. AGED concluded that this technology could be of significant use to the DoD, and a thorough, well-funded program (approximately $50M per year over 5 years) should be initiated to develop the materials, fabrication, and packaging required.



Potential future benefits from wide bandgap technology include insertion into radars, UAVs, and decoys, seekers and jammers.

AGED recommended that the above funding be applied to the following areas:

1. Materials substrate development (4-inch SiC, GaN, and thermal modeling)

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[3] The full title for this STAR is “RF Applications for Wide Bandgap Technology.” The final report can be found on the AGED public Web site at http://aged.palisades.org/WBG.pdf. Information regarding this report is available from the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

2. Epitaxial growth development for RF applications
3. A comprehensive wide bandgap RF device and circuit technology maturation program
4. Development of a business plan to establish and maintain cost effective wide bandgap technology for DoD systems.

Detailed information on the findings and recommendations is in the report.

Electronics Packaging[4]

The field of electronics packaging deals with the process by which semiconductor chips can be molded into a form that can be integrated effectively into a larger microelectronics assembly. Military applications increasingly require smaller and smaller designs, or footprints – a requirement that, at the same time, is increasingly difficult to achieve due to limitations in packaging density and microchip integration levels. Simultaneously, the requirements for extracting the high level of performance achievable on-chip into the system have dramatically increased.

AGED, in a STAR on the topic, identified several increasingly important technical and infrastructure issues. For example, in order to develop and deploy multifunction solid-state based radar systems in the next 10 years, new unique DoD packaging technology will be needed which meets military environment specifications. Currently, insufficient attention and resources are being directed towards solving that problem. Also, to support defense contractor use of advanced custom multifunction packaging, a vendor infrastructure is required which will accept low volume DoD requirements.

It was recommended that an annual commitment, on the order of $10-15 million, should be partitioned among 3-5 packaging fabricators (i.e., $2-4 million/year/fabricator), to assure the DoD access to advanced packaging technologies long into the future. The best approach for the DoD would be to make arrangements that would include some combination of all four types of organizations (boutique-type packaging companies, Government facilities, FFRDCs and not-for-profit organizations) to assure that all possible packaging needs are addressed.

[4] The full title for this STAR is "Advanced Electronics Packaging For Military Applications." The final report is not yet available for public release. Information regarding this report is available from the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

Reliability of Electronic Components[5]

Reliability, the ability or capability of a product to perform a specified function in the designated environment for a minimum length of time or minimum number of cycles, is of critical concern to DoD applications, because, at some point, all components fail. A successful DoD-wide reliability effort helps to better manage these component failures, making such failure more predictable and allowing system designers to plan for efficient and cost-effective replacement of these components.

At present, packaging (addressed above) and the interconnection between electronic devices and components within a system represent the major reliability concerns for microelectronics used in defense applications. However, reliability of the actual devices themselves will become an increasing cause of failure in future systems. Continued trends in microelectronics have begun to encroach on fundamental physical limits. In this competitive commercial environment, manufacturers increasingly maximize chip performance within controlled environments at the expense of a lower peak performance that could be sustained over wider operating environments. Given that military requirements emphasize reliability over a wide range of situations, these commercial-based parts will become increasingly unreliable. There are, in general, two ways to address this: DoD can develop a separate capability where needed, or DoD can increase its efforts at modifying commercial products and processes to ensure better reliability of these devices in the field.

AGED studied the relevant issues in a STAR, which concluded with the following recommendations:

1. DoD should provide an appropriate level of S&T investment to assure reliable microelectronics operation for extended environments and extended lifetimes (both are military-unique parameters) to maximize the performance of future DoD systems and to minimize the life-cycle costs of future platforms.
2. DoD should encourage the formation of consortia among system suppliers, similar to those formed among automobile manufacturers, whenever such consortia do not interfere with competitive practices – for example, in “generic” components for standard operational functions, such as automotive engine controls.

In order to procure “leading-edge” parts DoD should exploit existing, or create where necessary, multidisciplinary reliability research and development centers to develop “physics-of-failure” models for knowledge-based qualification. Each center must be a trusted, honest broker that can protect the proprietary designs and processes of the chip vendors, while simultaneously protecting the applications requirements of the system and subsystem contractors.

[5] The full title for this STAR is “Reliability of Electron Devices for Defense Applications.” The final report is not yet available for public release. Information regarding this report is available from the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

Low-Cost Lasers[6]

Many current DoD mission areas require battlespace sensors and directed energy solutions. Vital military laser applications include range finders, illuminators, beam riders, and designators, and laser radar. Recent DoD studies describe the key enabling laser technologies needed in the future as a) agile multi-wavelength lasers and b) high efficiency electric lasers. Important mission areas include countermeasures, chemical warfare agent detection and identification, nighttime imaging, tunnel and underground structure detection, and tactical directed energy weapons. These laser systems need to be efficient, compact, lightweight, inexpensive, easily transportable and maintainable, rugged, reliable, and capable of operation in widely diverse environments. Unfortunately, current lasers often do not meet many of these requirements. To meet these requirements, DoD requires a new generation of solid-state laser technology.

An AGED STAR on low cost lasers recommended the development of an innovative program in laser technology, one that will bring optical manufacturing closer to the automated processes characteristic of the electronics industry. The basic goals will be to obtain higher efficiency, lower cost, and more reliable lasers. Success in this effort will result in the possibility of making well integrated, monolithic, inexpensive laser systems that are also rugged, stable and long-lived. This can be achieved by instituting strong S&T programs, coordinated with specific DoD missions and applications, at an investment of $25M per year over the next five years.

Infrared Countermeasure (IRCM) Lasers[7]

Infrared-seeking anti-aircraft and anti-ship missiles are a major concern for all branches of the military. Wide proliferation of advanced American, former Soviet Union, and third party-manufactured missile threats serves to complicate the situation. It is clear that new missiles, with countermeasure capabilities against flares and jammers, are currently being deployed and that more advanced missile threats loom on the horizon. The DoD has been aware of this situation for some time and continues to invest in technologies to counter this threat. One approach that offers significant advantages for defeating the current missile threat is laser-based IRCM that use Disrupt and Jam methods. However, developing the necessary moderate power, high beam quality, mid-infrared lasers necessary to meet the requirements has proven to be especially difficult. Packaging, environmental, reliability and cost constraints only further exacerbate this problem. Additionally, new laser-based approaches (such as Damage/Destroy) for countering imaging missile threats may have even more demanding laser requirements

[6] The full title for this STAR is “Low Cost, Mass Producible, Solid-State Lasers.” The final report is not yet available for public release. Information regarding this report is available from the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

[7] The full title for this STAR is “Infrared Countermeasure Lasers.” The final report is not available for public release. Limited-release and classified versions of the report are available upon request and verification of credentials. For more information, please contact the AGED Secretariat at information@palisades.org or at the contact information listed in the Executive Summary.

The topical STAR on this issue concluded that laser development activities for the IRCM mission area, in both industry and the Government laboratories, are currently funded well below the critical mass necessary to sustain the rate of technical advancement. Ongoing laser IRCM programs would clearly benefit from a relatively small but focused increase in their levels of funding. Particularly, several of the S&T laser development efforts evaluated by AGED promise substantial improvements (two-fold, ten-fold, or more) in both the output power and power density needed to meet the challenges of current and next-generation missile threats. However, a stronger technology base, sustained by both DoD and industry, is also necessary to continue the development and delivery of advanced IRCM laser sources.

Critical Technologies Identified Through DoD and Industry Interaction

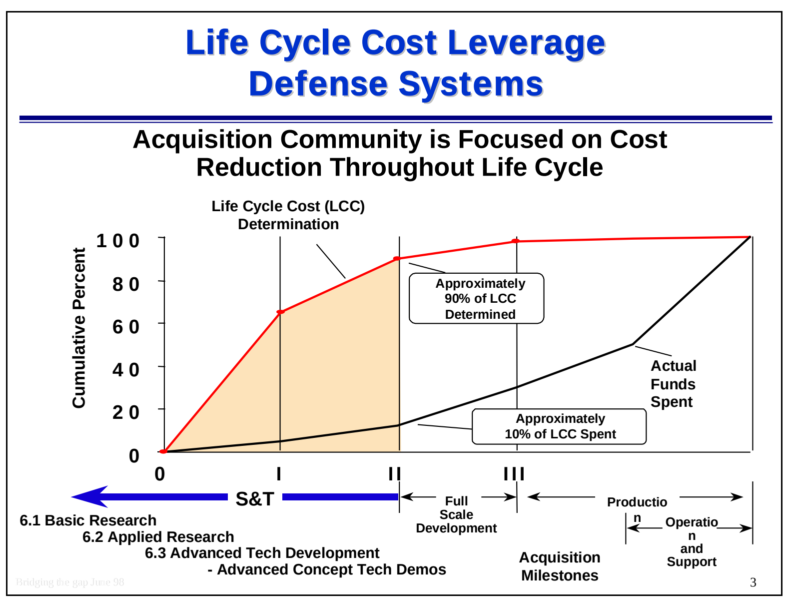
In addition to the technologies and practices reviewed through STARs, a number of crosscutting issues and technologies have been identified by AGED as having critical importance to DoD.

Technology Transition Efforts and Funding

Over the last decade, a new philosophy regarding the transition of promising technologies from the laboratory to military systems has become increasingly in vogue. Originally viewed as a cost-saving measure, the DoD has curtailed its funding of this transition approach and shifted the burden for this activity to the systems' prime contractors. While a significant cost savings has been realized during this time, the longer term effects of this thinking are only now coming to light. In some cases, the prime contractors opted to use already-available technologies rather than fund the transition of the new technology into their systems. In many other cases, they funded this transition themselves, which resulted in cost overruns for their systems, as this cost was not originally factored into these programs.

At face value, this is perhaps not a problem, however the evidence on balance suggests otherwise. Developing technology at the system level is prohibitively expensive in comparison to developing that technology in the laboratory.

Worse, these single-solution efforts lead to two undesirable results. First, the solution developed and implemented by the systems prime contractors tend to be optimized for their systems only. This leads to what is referred to as "stove-piping" of the technology, and makes it difficult, if not impossible, to apply the implemented solution to other programs. Thus, if a given technology is desired for N systems, N solutions are developed. This can be vastly more



System costs are determined early in the process, where investment in transition technology can reap cost savings of several orders of magnitude over the system's life cycle.

expensive, both in terms of cost and time, than the proactive transitioning of these technologies to the industry.

Second, single-solution efforts focus on solving only an immediate need, not a long-term need. Many technologies are developed to address long-term problems, and these technologies by definition are less likely to be transitioned by the systems primes. In these cases, DoD's entire investment in this technology is wasted for lack of the needed funding to transition that technology and make it widely available to the developers of other technologies. An excellent example of this kind of technology is modeling and simulation that also must include validation. In this case, developing accurate modeling and simulation of electronic devices and components does not apply to any given military system, however the development of these tools can yield cost reductions on several orders of magnitude in the development of these devices and components in the future. It is this type of effort that is in the greatest need of DoD leadership.

Service Laboratory Personnel and Funding

Over the course of the past several years, AGED has observed a steady decline in the number of military laboratory sensors and electronics personnel, primarily due to steeply declining funding. The erosion of personnel and the difficulties in attracting and retaining new expertise have made it increasingly difficult for the laboratories to properly support the warfighter.

In the electronics area in particular, this problem is exacerbated by the attractive compensation and award packages offered by commercial entities. In the past, this effect was attenuated by the lure of working with unique cutting-edge technology. The Service laboratories continue to serve their vital role in the development and maturation of cutting-edge technologies. However, as the military's lead over the corresponding commercial sectors has dwindled, so has the attraction of working in the Service labs.

These staffing concerns are exacerbated by the instability of funding in Service laboratories. This instability makes planning for present and future personnel needs difficult. Further, this fluctuation in support for various S&T efforts at the Service laboratories makes retaining the expertise to accomplish this work extremely difficult. In this area, funding increases per se are not necessary, but funding stability is paramount.

Solutions to this staffing problem are widely discussed, but are ultimately political in nature in that they typically involve changes to the hiring and compensation rules for these government employees. Endorsing such a solution is thus beyond AGED's scope.

Vacuum Electronics/Solid State Technology Investment Balance

For many years, a tension has existed between the solid-state and vacuum electronics S&T communities regarding the scope and level of funding. This tension has been created, and is fed, by the misperception that these technologies are parallel paths to identical solutions, and therefore funding both sets of technologies is redundant. The fact is that these technologies are in many ways complementary, not overlapping, and the solution for many DoD needs requires a combination of these technologies.

Both technologies offer unique advantages and abilities that cannot be satisfied by the other technology. Emphasizing one technology over the other is counterproductive.

Recently, DoD has undertaken efforts to address this problem, prompted both by internal reviews as well as congressional direction. One key effort involves the Ad Hoc Solid-State and Vacuum Electronics Tri-Service Committee, formed in 1999.[8] These efforts are admirable, and have helped to defeat the perception that investment in these areas is a zero-sum game. AGED endorses this approach without reservation.

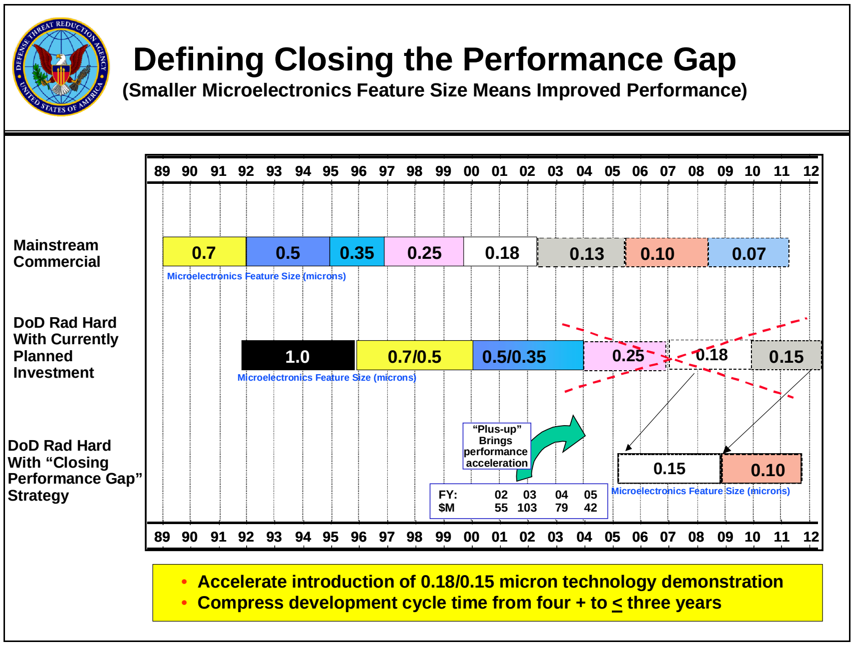
Radiation Hardened Electronics Technology

Radiation hardened electronics technology represents a fundamentally unique military requirement. It is one of few technology areas in which the overlap with the commercial sector is negligible, and in which that overlap will remain minimal for the foreseeable future. The commercial sector is singularly focused on the need to protect commercial satellites from cosmic radiation. The military, however, must also contend with the dangers of nuclear radiation, and must protect many ground-based systems from this threat as well as protecting its space-based assets. Further, as is more generally the case with electronics, the military's power and durability requirements for space are dramatically more robust than those of the commercial market.

Given the uniqueness of this need, identifying and keeping suppliers for military-appropriate radiation hardened electronics is difficult. In the past, DoD and Congress have endorsed the need to explicitly support two competing suppliers, and that support has, by necessity, included support for these suppliers' infrastructure as well as ensuring that they have a market in which to sell their products (i.e., ensuring a stable military demand).

[8] This report is available from the AGED public Web site at http://aged.palisades.org/VE-SS_Report.pdf.

In spite of widespread recognition of these facts, appropriate funding continues to be subject to uncertainty. This makes life unduly hard for suppliers and military system planners alike, to no apparent benefit of any party.



The DDR&E's Advanced Electronics Initiative aims to close the performance gap between radiation-hardened electronics and commercially-available electronics, providing dramatic increases in performance to DoD weapons and space systems.

Concluding Remarks

The Advisory Group on Electron Devices was established to provide the DoD with advice and insight regarding its electronics science and technology (S&T) programs. This report serves to identify issues critical to the DoD's electronics community and bring them to the attention of the stewards of the DoD's electronics S&T programs. In a world where electronics technology is proliferating around the globe, maintaining the DoD's technological superiority in this area is more difficult – and yet more critical – than ever before.

The Prime Directive of AGED's mission, as it were, is to help ensure that the DoD has access to the electronics technology it needs. Central to accomplishing this directive are:

- Robust and forward-looking technology development efforts
- Proactive transitioning of these new technologies to the manufacturers and prime contractors who can best utilize them, and
- Understanding how these electron devices and components age over time and anticipating – and compensating – for that aging process in the context of system life-cycle maintenance

In the pages above, several electronics technologies and technology issues are discussed. This is not intended to be an exhaustive evaluation. As the report's title implies, it is a spotlight of the most critical electronics S&T issues facing the DoD today – issues that require immediate comprehension and attention.

For more information on the Advisory Group on Electron Devices, AGED's mission and its activities, please contact the AGED Secretariat.

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List of AGED Members

AGED consists of the core Advisory Group and its component Working Groups, as described above. Membership of these Groups consists of key personnel in electronics science and technology from government, industry and academia. Dr. Susan Turnbach, ODDRE(S&T), serves as the AGED Executive Director. A partial listing of its membership is listed below.

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